
ANALYSIS OF PROCESS PARAMETERS IN DRY MACHINING OF EN-31 STEEL by GREY RELATIONAL ANALYSIS

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ABSTRACT

This paper presents the optimization of surface roughness & material removal rate in dry turning of EN-31 steel. Carbide inserts were used for machining of EN-31 to study effects of process parameters [Cutting speed (S), Feed (F) and depth of cut (d)]. These models can be effectively used to predict the surface roughness (Ra) of the workpiece.

The big challenge of the Micro, small & medium industries in India for achieving high quality products with increased productivity. Paper presents work of an investigation of turning process parameters on EN-31 material, for optimization of surface roughness, material removal rate. The experiment is carried out by considering three controllable input variables namely cutting speed, feed rate, and depth of cut. The design of experiment and optimization of surface roughness is carried out by using Taguchi L9 orthogonal array & Grey Relational analysis.

Keywords: EN-31, Surface roughness (Ra), Speed (S), Feed (F), Depth of cut (d)

1. INTRODUCTION

One of the most important methods in production of metal parts is machining. Turning is the most widely used machining processes that may result in high precision and quality and increased productivity. However, the quality of final product and its production cost heavily depend on process parameters values. Single purpose control and process optimization can't satisfy economic demands such as reducing time and costs with maintaining quality at the same time. This is because quality improvement usually increases production costs and thus productivity decreases. The use of traditional optimization methods such as differential measures and enumeration of all possible solutions is not very efficient and accurate.

Machining by turning involves the use of a lathe and is used primarily to produce cylindrical or conical parts. It is valuable to increase tool life, to improve surface roughness, to reduce cutting force and material removal rate in turning operations through an optimization study. Among these

four characteristics, surface roughness and material removal rate play the most important roles in the performance of a turning process. Cutting speed, feed rate, depth of cut, tool-workpiece material, tool geometry, and coolant conditions are the turning parameters which highly affect the performance measures. In order to improve machining efficiency, reduce the machining cost, and improve the quality of machined parts, it is necessary to select the most appropriate machining conditions.

In Micro, small & medium industries (MSME) in India have made very great progress [13], main drawback with MSME industries is the optimum operating parameters of the machines. It has long been recognized that conditions during cutting such as feed rate, depth of cut, cutting speed, nose radius should be selected to optimize the economics of machining operations. In machine tool field turning is valuable process. Machining of steel is an interesting topic of today's industrial production and scientific research. Turning process for steel is preferable thing compared to grinding process & now days this process is alternative to many finishing processes such as grinding. A major factor leading to the use of turning in place of grinding has been the development of cubic boron nitride (CBN) cutting tool insert, which enable machining of high-strength materials with a geometrically defined cutting edge. The main advantage of precision turning over grinding include lower production costs, higher productivity, greater flexibility, elimination of grinding fluids, and enhanced work piece quality.

In this article, a multi objective optimization model for CNC turning of EN-31 Steel. The multiple performance characteristics include material removal rate (MRR) and surface roughness (SR). Three important machining parameters; namely cutting speed, feed rate and depth of cut are considered as the input process parameters. The analysis of variance (ANOVA) is also conducted to estimate the relative effect of each process parameters.

2. LITERATURE REVIEW

The experimental investigations conducted by Dilbag Singh and P. Venkateswara Rao with mixed ceramic inserts made up of aluminum oxide and titanium carbide nitride (SNGA) exhibited the effect of cutting conditions and tool geometry on surface roughness in finished hard turning of EN-31 steel. The primary influential factors that affect the surface finish are cutting velocity, feed, effective rake angle and nose radius; dominant factor being feed followed by nose radius and others [1]

S.K. Choudhury, I.V.K. Appa Rao presented a new approach for improving the cutting tool life by using optimal values of velocity and feed throughout the cutting process. The experimental results showed an improvement in tool life by 30%. [2]

D.V. Lohar have evaluated the performance of MQL system during turning on hard AISI 4340 material by using Taguchi method. They have used the feed rate, cutting speed, depth of cut as process parameter for analysis of cutting forces, surface roughness, cutting temperature & tool wear. They have found that cutting force & temperature is less in MQL system Compared to the dry & wet lubrication system. The surface finish is also high in case of MQL system. [3]

Y.B. Kumbhar investigated tool life and surface roughness optimization of PVD TiAlN/TiN coated carbide inserts in semi hard turning of hardened EN31 alloy steel under dry cutting conditions using Taguchi method. They have concluded that the feed rate was the most influential factor on the surface roughness and tool life. [4]

Ilhan Asiltürk, Harun Akkus focused on optimizing turning parameters based on the Taguchi method to minimize surface roughness by using hardened AISI 4140 (51 HRC) with coated carbide cutting tools. Results of this study indicate that the feed rate has the most significant effect on surface roughness. In addition, the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important [5]

RavinderTonk, have investigated the effects of the parametric variations in turning process of En31 alloy steel. Taguchi's robust design methodology has been used for statistical planning of the experiments. Experiments were conducted on conventional lathe machine in a completely random manner to minimize the effect of noise factors present while turning EN31 under different experimental conditions. The analysis of results shows that input parameter setting of cutting tool as carbide, cutting condition as dry, spindle speed at 230 rpm, feed at 0.25mm/rev and depth of cut at 0.3 mm has given the optimum results for the thrust force and input parameter setting of cutting tool as HSS, cutting fluid as soluble oil, spindle speed at 230 rpm, feed at 0.25 mm/rev and depth of cut at 0.3 mm have been given the optimum results for the feed force when EN31 was turned on lathe. [6]

M. A. H. Mithu et al have evaluated the effect of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil based cutting fluid. They have found that chip-tool interface temperature as well as tool wear gets reduced. [7]

Nikhil RanjanDhar evaluated the performance of MQL system on tool wear, surface roughness and dimensional deviation in turning AISI-4340 steel by using cutting speed, feed rate, depth of cut as controllable variables. They improved the tool life in MQL system. [8]

C. R. Barik studied the parametric effect & optimization of surface roughness of EN-31 material in dry turning. They concluded that feed rate has more effect on surface roughness. [9] L. B. Abhang investigated the effect of MQL during turning of EN 31 alloy steel for analysis of cutting temperature, cutting force, surface roughness. They found that quality of product as well as tool life get improved. [10]

Ashish Bhateja conducted there project work for Optimization of Different Performance Parameters i.e. Surface Roughness, Tool Wear Rate & Material Removal Rate with the Selection of Various Process Parameters Such as Speed Rate, Feed Rate, Specimen Wear , Depth Of Cut in CNC Turning of EN24 Alloy Steel.[13]

A.D.Jewalikar conducted the experiments for Hard Part Turning for the optimization of the Hard Part Turning for Bohler K110 material in dry machining.For Surface Roughness (Ra) Cutting speed is the dominant factor followed by feed and depth of cut. Therefore regression model can be effectively used to predict the surface roughness within the specified range of cutting parameters which were used while investigation. [14]

From the literature review, it is observed that less research work has been seen for En31 Alloy Steel in CNC turning in dry cutting system.

3. EXPERIMENTAL CONDITION

Many factors affect the surface roughness in turning process. The important machining parameters include feed rate (F), depth of cut (D) and cutting speed (S).

The composition of material is as follows;

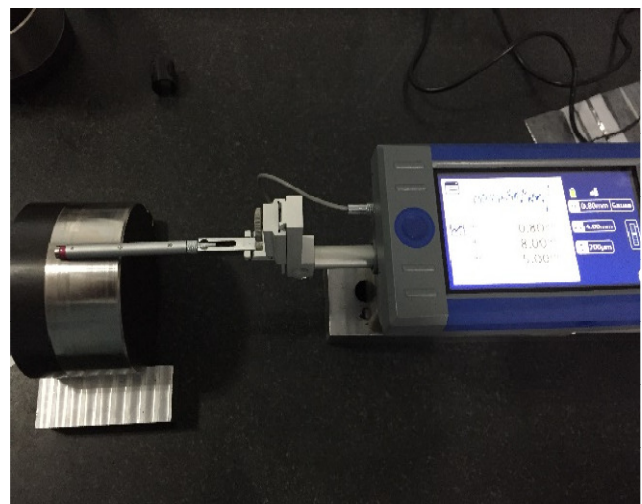
C	Si	Mn	Cr	Co	S	P
0.9-1.2%,	0.10-0.35%	0.30.75%	1-1.6%	0.025%	0.05%	0.05%

Experimental work was carried out on CNC turning machine (HAAS-SL20). A round bar (ϕ 50 mm \times L 50 mm) of EN-31 steel was turned for each parameter combination tested. The cutting was performed by using turning inserts (CNGA 120408 THM) by WIDIA CVD coated with Ti(C, N)/TiN/Al₂O₃ which could provide higher heat resistance, under dry conditions. The objective of the experiments was to secure the advantageous outcomes such as minimum surface roughness, less heat generation, minimum tool wear, better geometrical accuracy and compressive stresses favorable

for carbide edges. Measurements of surface roughness were conducted in order to characterize the process and determine the optimal operation conditions. For every operation a cut of 25 mm was taken. Also for every operation new insert was used. After each cut, the surface roughness was measured on the surface table with the help of surface roughness tester (Taylor Hobson) having cut off length 0.8 mm and evaluation length 25 mm. Three spots on each turned work piece were used to measure the surface roughness of the cut. The measured values of surface roughness for 9 experiments are presented in Table 2. A well-planned design of experiment can substantially reduce the number of experiments.



CNC Lathe machine –SL 20



Taylor Hobson Surface Tester

The grey system theory proposed by Denghasbeen proven to be useful for dealing with poor, incomplete and uncertain information. The greyrelational analysis is based on the grey system theory and can be used to solve complicated interrelationshipsamong multiple performancecharacteristics effectively.

3.2 Process Variables

Cutting speed, feed rate, and depth of cut, MRR. All these parameter are used at their lowest and highest level by considering machine specification.

Sr.No	LEVEL	CUTTING SPEED (mm/min)	FEED RATE (mm/rev)	DEPTH OF CUT(mm)
1	LOW	100	0.1	0.1
2	MEDIUM	200	0.25	0.5
3	HIGH	300	0.4	1.0

3.3 Response Variables

Surface roughness

4. ANALYSIS OF SURFACE ROUGHNESS

The following table shows the readings of surface roughness obtained in dry system at different level of feed rate, cutting speed, depth of cut.

RUN ORD.	C.S	F.R	D.O.C.	S.R
1	100	0.10	0.10	0.80
2	100	0.25	0.50	1.2
3	100	0.40	1.00	5.6
4	200	0.10	0.50	0.68
5	200	0.25	1.00	0.89
6	200	0.40	0.10	2.32
7	300	0.10	1.00	1.42
8	300	0.25	0.10	1.08
9	300	0.40	0.50	3.40

4.1 Response Optimizer

Data pre-processing is normally required, since the range and unit in one data sequence may differ from others. It is also necessary when the sequence scatter range is too large, or when the directions of the target in the sequences are different. In this study, a linear normalization of the experimental results for surface roughness were performed in the range between zero and one, which is also called the grey relational generation. The normalized data processing for SR corresponding to lower-the-better criterion can be expressed as:

$$X_{ik} = \frac{\max(y_{ik}; i = 1, 2, \dots, n) - y_{ik}}{\max(y_{ik}; i = 1, 2, \dots, n) - \min(y_{ik}; i = 1, 2, \dots, n)}$$

Where $X_i(k)$ is the value after the grey relational generation, $\min y_i(k)$ is the smallest value of $y_i(k)$ for the k th response, and the $\max y_i(k)$ is the largest value of $y_i(k)$ for the k th response.

The Grey relational generation is given in Table 4.

Sr. No	speed	feed	doc	Ra	S/N Ratio	Normalise d S/n Ratio	Deviation Sequence	Grey RlnCoeff- Ra	GRG	Ranking
1	100	0.1	0.1	0.8	1.94	0.0771	0.9229	0.3514	0.5873	2
2	100	0.25	0.5	1.2	-1.58	0.2694	0.7306	0.4063	0.5517	5
3	100	0.4	1	5.6	-14.96	1.0000	0.0000	1.0000	0.3333	9
4	200	0.1	0.5	0.68	3.35	0.0000	1.0000	0.3333	0.6000	1
5	200	0.25	1	0.89	1.01	0.1276	0.8724	0.3643	0.5785	3
6	200	0.4	0.1	2.32	-7.31	0.5821	0.4179	0.5447	0.4786	7
7	300	0.1	1	1.42	-3.05	0.3492	0.6508	0.4345	0.5351	6
8	300	0.25	0.1	1.08	-0.67	0.2194	0.7806	0.3904	0.5615	4
9	300	0.4	0.5	3.4	-10.63	0.7633	0.2367	0.6787	0.4242	8

Basically, the larger normalized results correspond to the better performance and the best-normalized result should be equal to one. Next, the grey relational coefficient is calculated to express the relationship between the ideal (best) and actual normalized experimental results.

The grey relational coefficient can be calculated as:

$$\xi_i(K) = \frac{\Delta_{min} + \zeta \Delta_{max}}{\Delta_{0i}(k) + \zeta \Delta_{max}}$$

$$\Delta_{min} = \min_{j \in i} \min_k \|y_{(0)}(k) - y_j(k)\|$$

Denotes the sequence and $y_j(k)$ denotes the comparability sequence. ζ is distinguishing or identified coefficient. The value of ζ is the smaller and the distinguished ability is the larger. $\zeta = 0.5$ is generally used.

After averaging the grey relational coefficients (Table 4), the grey relational grade can be expressed as

$$\gamma_i = \frac{1}{n} \sum_{k=1}^n \xi_i(k)$$

Parameters	Level I	Level II	Level III	Max-Min	Rank
speed (A)	0.4908	0.5524	0.5069	0.0616	2
feed (B)	0.5741	0.5639	0.412	0.1621	1
Doc (C)	0.5425	0.5253	0.4823	0.0602	3

7. CONCLUSION

The experimental results show that the optimal cutting parameters are high cutting speed 200 mm/min, lower feed 0.25 mm/rev and lower depth of cut 0.1 mm, gives the 1 surface roughness (SR) within the range of experiments based on the average grey relational grade.

8. ACKNOWLEDGEMENT

The author is very much thankful to the Indo German Tool Room (IGTR), Aurangabad for their technical support during the experimentation

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